DENTAL ANATOMY

T. W. WIDDOWSON.

NOTES ON

DENTAL ANATOMY,

(A POCKET TOMES.)

ARRANGED BY

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PREFACE.

The writer does not wish his readers to believe that this is an original work. It constitutes to a great extent, as the name implies, an abridged "Tomes," to which has been added the most imp rtant theories, etc., of other authorities upon the subject. It is intended for use in conjunction with Tomes' "Dental Anatomy," and Hopewell Smith's "Histology and Patho-Histology of the Teeth," with the desire that it may be of value to the dental student in simplifying the mass of matter dealing with the subject of dental anatomy, and in furnishing a foundation upon which to build future knowledge.

The writer wishes to acknowledge the great help he has received from the published works of Mr. Charles Tomes, Mr. Hopewell Smith, and Mr. Howard Thompson, in the compilation of these notes.

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ERRATA.

Before perusal the following errata should be noticed and the IMPORTANT alterations made.

Page	1,	line	15	for	"flour" read "fluor."
,,	9	,,	14	,,	"flouride" read "fluoride."
,,	16	,,	13	,,	"homogenous" read "homogeneous."
,,	30	,,	8	,,	"develope" read "develop."
,,	30	,,	14	,,	"develope" read "develop."
,,	51	,,	21	,,	"phagasitosis" read "phagocytosis."
,,	63	,,	23	,,	"pre-milk" read "permanent."
,,	64	,,	2	,,	"milk tooth" read "post permanent tooth."
,,	73	,,	18	,,	"gill" read "file."
,,	74	,,	17		omit the words "or leptocardii."

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Notes on Dental Anatomy.

(A Pocket Tomes.)

CHAPTER I.

ENAMEL—*Definition.*

Enamel is an inorganic substance composed of lime salts, deposited in particular patterns, and formed under the influence of organic tissues which have disappeared during formation. (Tomes)

Properties, etc.,—hard, brittle, bluish white, semi-translucent. In perfect form it is the hardest tissue in the human body. It contains no organic matter. The external surface is finely striated, the striae being transverse to the long axis of the crown.

Composition—

Salts	calc. phos , calc. carb., calc. flour, mag. phos., etc., about	96 p.c.
Water	....	4 ,,
Organic matter	....	none.

Tomes' proofs of non-existence of organic matter :—

(1) Does not char on heating.

(2) On heating enamel in a flask and collecting what is given off in a calcium chloride tube and then analysing, the substance given off is found to be 4 per cent. of water, the 96 per cent. remaining being inorganic salts.

Prisms.—Enamel is fibrous, and can be split up into prisms, which in transverse section are hexagonal. The prisms run from the dentine to free surface.

In *human* they have a decussating course

In *eel* no structure visible.

In *manatee* they are straight.

In *sciuridae* divided into inner and outer portions, being thus more complex.

In *beaver* still more complex (outer and inner layer.)

In *porcupine* ditto ditto.

In *leporidae* (hares and rabbits) no lamelliform arrangement, the prisms being slightly flexuous.

In the *rat* the prisms are serrated.

Theories upon structure of enamel :—

Bodecker's.—Enamel is composed of calci-

fied rods or prisms, between which is an active protoplasmic matrix continuous with the contents of the dentinal tubes. This active protoplasm sends thorns into the prisms at right angles to their length. Between the enamel and dentine are masses of active protoplasm.

Klein's.—In the first instance the enamel cells are separated by an organic substance, and the remains of the substance must be present between the completed enamel prisms.

Von Ebner's.—There is an organic substance between the prisms, traceable into continuity with Nasmyth's membrane.

Leon Williams.—The enamel prisms are regularly beaded, each being composed of rods joined by varicosities. The varicosities lie side by side and do not interdigitate. The interprismatic substance is of a somewhat similar structure to the prisms, but of a lower order.

In fracture of enamel the fracture runs through the centre of the prisms and not through the interprismatic substance.

Markings (microscopically). Each prism presents faint transverse striations. These are marked in the rat (due to serrations).

Theories for this Striation—

1 Intermittent calcification.
2 Varicosities (Leon Williams).
3 Bodecker's thorns.
4 Irregularities on surface of rods.
5 Acids in mounting. (Von Ebner.)

Brown striac of Retzius.—Brownish lines parallel neither to surface of enamel nor dentine, seen in longitudinal section, running obliquely transverse to the long axis. Well marked in the crocodile.

Theories for appearance.—

1 Pigmentation.
2 Lamellated mode of formation of enamel.
3 Air spaces.

Schreger's Lines.—Seen only in longitudinal section, and according to Hopewell Smith, by either reflected or transmitted light, and are lines dependent upon the different directions of the contiguous groups of enamel prisms.

Pigmented Enamel.—Found in human teeth, in teeth of some rodents (Beaver) and some insectivora.

Cause.—May be due to kinds of food upon which animal subsists.

Tubular Enamel.—Two ways in which tubes enter enamel.

1 From without.

2 From dentine.

Examples of (1)

Sargus.—The tubes run at right angles from the external surface proceeding inwards, and then bend abruptly at an angle forming branches which sometimes pierce the dentine.

Cestracion Philippi.—Tubes open upon the external surface by large mouths and as they pass inwards they are gathered into bundles.

Lamna.—

Examples of (2).

Marsupials except Wombat. Hyrax, some fish (serassalmo and barbel), some insectivora (soricidae), some rodents (jerboa), and fossil fish (spherodus).

Two theories *re* positions of tubes.—

1 Enter between prisms (Prof. Paul).

2 Tube in centre of prism (Tomes), e g. Marsupials. With respect to Marsupial enamel, Von Ebner states that the tubes are not in the axis of prisms.

Enamel spaces or Spindles. — Situated in enamel near to junction with dentine, and are

continuous with any dentinal tubes which pass into enamel appearing to be enlargements of them. More numerous in connection with enamel of cusps. In fresh condition are probably filled with protoplasm (Hopewell Smith).

Theories regarding contents—

1 Air.

2 Calcareous masses.

3 Protoplasm.

Distribution of Enamel—

In teeth of *limited* growth it stops at the neck.

In teeth of *persistent* growth it goes to base of tooth.

It may be confined to front and sides (incisor of rodent).

It may be confined to front only (incisor of wombat).

It may be very thick (incisor of aye-aye).

It may be merely a tip (eel, elephant's tusk, hake.)

It is absent from edentates, the molars of the dugong, the canines of the sus-babirusa, some reptiles, the teeth of the Narwhal, and some fish.

According to Choquet, the enamel in human

teeth overlaps the cementum more often than cementum overlaps enamel. The two tissues are more often in contact with one another without overlapping.

CHAPTER II.

DENTINES.

Classification.

I. *Dentines developed on the surface of the pulp.*

a. Hard unvascular dentine.

b. Plici dentine.

c. Vaso dentine.

II. *Dentines developed within pulp.*

d. Osteo dentine.

e. Secondary dentine.

(a). *Hard unvascular dentine.*

This occurs in man and many mammals.

Definition.—An organic matrix impregnated with lime salts, and permeated with tubes which radiate outwards from a simple pulp chamber (Tomes).

Properties.--Yellowish white, hard, elastic. Fractured dry dentine is lustrous, due to the presence of air in the tubes. When the lime salts have been removed by acids, the matrix yields a cartilagenous substance. If this be boiled for some time gelatine results with a small residue of elastin.

Composition.—Organic matter, 26 per cent.

Water ...		8 ,,
Salts—Calc. Carb.	}	66 per cent.
Mag. Carb.		
Calc. Phos.		
Mag. Phos.		
Calc. Flouride, &c.		

In the dentine or ivory of the Elephant, there is about 45 per cent of organic matter. The dentinal tubes are finer, there is a greater number of secondary curvatures, and also interglobular spaces, thus rendering the dentine of the elephant more elastic than man's.

Structure.—Human dentine is fibrous, but has usually no visible structure this being masked by the dentinal tubes. According to Mr. Mummery, carious or decalcified dentine shows an appearance like that of connective tissue fibres. This may also be seen in vaso-

dentine where there are no tubes to hide the structure.

Dentinal Tubes.—Each tube starts upon the surface of the pulp, then runs out towards the periphery becoming smaller and breaking up into two branches, these joining together and forming loops. At the pulp the diameter is greater, and they are very closely packed so that there is not much room for any matrix. Near the surface they are more widely separated. The tubes describe larger and smaller *curvatures.* The larger are known as the *primary curvatures.* They are italic *f* shaped, less numerous and abrupt than the smaller, and are seen better in the crown than in the root. They are spirally twisted, and so produce the smaller or *secondary curvatures*, which are more numerous and more marked in the roots.

The tubes end either—

1 By anastomosing and forming loops.
2 Ending in fine points in dentine.
3 Passing into interglobular spaces.
4 Ending in lacunæ and canaliculi incementum.

5 Passing into enamel spindles. (Hopewell Smith.)

6 Passing into enamel.

In a *transverse section* of dentine, rings are seen concentric with the pulp. They are described by two men as follows, viz.:—

1. Schreger.— Schreger's Lines are lines running parallel with the exterior of the dentine, and are due to the coincidence of the primary curvatures of the dentinal tubes.

2. Owen.—Contour lines of Owen or Incremental lines of Salter. Owen describes them as does Schreger, and also as being due to rows of interglobular spaces. Well marked in the tusk of the Walrus.

Dentinal Sheaths of Neumann—are the indestructible linings of the tubes, resistent to the action of acids and alkalies. They are formed of elastin and stain black with $AgNo_3$, (Golgi's Method.) They cannot be fully demonstrated except by partial destruction of the dentine matrix. Much discussion has arisen with respect to the existence of these so-called sheaths. Tomes asserts that they do exist, and are distinct from either the fibrils or the matrix, whilst others assert that the outer

portion of the fibrils is the sheath. Suddoth and Underwood doubt the existence of a sheath. Whether, however, a sheath exists or not, the action of acids upon dentine renders it safe to assert that the portion of substance directly surrounding the fibril differs from the greater portion of the dentine matrix in the degree of its calcification.

Dentinal Fibrils.—Each tube is occupied by a fine fibril, connected according to Magitôt, with the odontoblastic layer of the cells beneath. The fibrils do not stain readily, and although their function is both nutrient and sentient, they are not true nerves. They are difficult to stain, and are surrounded by a serous exudation which prevents injury. They are of some size, and when the tubes are fractured they stick out so straightly as to appear stiff.

Theories *re* their connection with odontoblasts:—

Magitôt.—The nerves of the pulp are continuous, with a reticulate layer of cells beneath the odontoblasts. These freely communicate with the odontoblasts which themselves are connected with the dentinal fibrils, so that

there is a direct line of communication between the fibrils and the pulp.

Klein and others.– The fibrils pass between the odontoblasts to the deep cells of the pulp, and are not connected with them.

Interglobular spaces or granular layer of Tomes. Found in dentine just below the cementum and the enamel. Seen under a low power they present a granular appearance. Although common they should not be regarded as truly normal, but as indications of arrests of development at the points where they occur. They are not true spaces, but contain either a soft plasm or a hard matrix. If a soft plasm, the tubes run round them; if a hard matrix, through them. They may be stained with carmine or a deep black with silver nitrate. They are well marked in the cetacea and in the crocodile.

Lamellae or laminae.—Lines seen occasionally near to the periphery of the dentine running at right angles to the tubes and parallel to the external surface of the pulp, and are probably caused by the manner in which the tissue has been built up, in strata. (Hopewell Smith.)

(b) *Plici dentine.*

Definition.—An organic matrix impregnated with lime salts and permeated by tubes which radiate outwards from a pulp rendered complex by the folding in of its walls.

The structure, composition, and properties are like those of hard unvascular dentine.

Examples exist in the Varanus or Monitor lizard, in which the upper half of the tooth is ordinary hard tubular dentine, and the lower half plici-dentine arranged like a paddle-wheel.

Lepidosteus oxyurus which has simple inflections.

Lepidosteus spatula, which has branched inflections and a pulp chamber filled up.

Labyrinthodon, which has radiating plates of dentine.

Rays, skates, myliobates, pristis, aardvark, selachi-maxima or basking shark, and wolf-fish.

(c) *Vaso-dentine.*

Here dentinal tubes are absent, but canaliculi exist with blood circulating through them. The pulp can be pulled out, being of simple form. The matrix is slightly laminated and its structure is fibrous. In the hake and other

examples there exist faint thorn-like processes running out from the vascular canals. The latter radiate outwards from the periphery of the pulp. Examples exist in the hake, cod, flounders, haddock, two-toed sloth, extinct megatherium, chaetodonts, and the priucipal cusp of the ornithorhynchus.

It is but rarely that the vascular canals occur in human dentine. The remains of vascular canals occur in the sargus, manatee, and tapir.

(d) *Osteo-dentine.*

This is formed within the pulp. Here calcified trabeculæ shoot through the pulp dividing it into small portions, so that there is no clearly defined pulp margin. There are small canals (canaliculi), but no long dentinal tubes. Large irregular spaces exist containing pulp tissue and blood-vessels. Examples occur in the pike, sharks, and other fish.

In the pike, there is a surface layer of ordinary tubed dentine. Beneath this layer the structure is osteo-dentine.

(e) *Secondary dentine* is formed within the pulp, and may be found in connection with any of the before-mentioned varieties, and

may be structureless or irregular. It occurs in elephant's tusks and whale's teeth, and teeth growing from persistent pulps. In connection with the human pulp there are several pathological varieties, viz.,

Areolar, which contains a large number of interglobular spaces, is formed rapidly, and is the commonest variety.

Fibrillar, is like normal tubed dentine. There is a bend between the tubes of the normal dentine and the secondary, and the boundary zone between the two is well marked.

Hyaline is formed slowly, and is homogenous.

Cellular and Laminar.

CHAPTER III.

CEMENTUM.

In the teeth of man this tissue exists as a covering over the roots, and what is now regarded as a membrane (Nasmyth's), was once supposed to be cement. In such teeth as the molars of the elephant, the capybara, and the wart hog, the denticles are fused together by cementum. It exists over the crowns of teeth of ruminants, is often thickened by disease (exostosis), and sometimes joins the roots of teeth together (gemination). In a single-rooted tooth it is thickest at the apex. Where there is more thon one root it is thickest at the bifurcation. It is absent in anchylosed teeth.

Structure. According to Hopewell Smith, human cementum is nearly structureless. Cementum taken from the neck of a tooth appears to be so, both lamellæ and lacunæ being

D

absent or very ill marked. Thick cementum or cement taken from the tooth of a ruminant, however, appears to be similar in structure to bone. It is a calcified matrix containing lamellæ, lacunæ, canaliculi, aud perforating fibres. Haversian canals do not exist. In exostosed cement, however, and then in rare cases vascular canals sometimes occur. The matrix yields gelatine on boiling, and if decalcified, becomes soft and pliable but retains its shape, being thus chemically like bone. It is also developed like bone in two ways, in membrane and in cartilage.

Lamellæ. These, as seen in transverse section, are rings running concentric with the pulp, and are thinner towards the neck of a tooth than towards the apex, but there is the same number in all positions. When the cementum is completed, there are few lamellæ. They are well marked in the cetacea.

Incremental lines of Salter. These are the lines or markings running in the direction of the lamellæ showing the manner in which cementum is built up, in strata.

Lacunæ are spaces elongated iu the direction

of the lamellæ, and contain cementoblasts, being also furnished with canaliculi. They are numerous in cetacea.

Canaliculi. Are the processes of the lacunæ. They are given off mostly at right angles to the lacunæ, and chiefly from the external borders, differing thusly from bone canaliculi, which are given off from all sides of the lacunæ and in all directions. The canaliculi of cement are also longer and more numerous than those of bone. The cementoblasts communicate with one another through the canaliculi, and those near to the external surface with the periosteum, hence a pulpless tooth is not always a dead tooth, as it may still receive nutrition from the periodontal membrane.

Encapsuled lacunæ. Sometimes lacunæ furnished with short processes are contained within well defined contours. They are individual cementoblasts or nests of cementoblasts which during calcification have preserved to some extent their individuality. An example occurs in the cementum of the horse.

Perforating canals and fibres. These pass into the cementum at right or acute angles to it and

bind it externally. The canals may extend half way through the cementum, and Black believes that the fibres are the calcified or semi-calcified remains of the principal fibres of the peridontal membrane. (Hopewell Smith.)

Sharpey's fibres. These are white connective tissue fibres contained in canals. They pass through all the lamellæ of the cementum where they are not fully calcified.

THE PULP.

This occupies the central portion of the tooth. It was formerly the dentine papilla, and therefore the formative organ of dentine, and eventually becomes its nervous and vascular supply. It varies in anatomical form according to age. In advanced age it diminishes in size, progressive calcification producing a deposit upon the walls of the cavity. Eventually the odontoblasts may atrophy and the fibrous tissue become well marked. It (the pulp), may become reddish brown in colour due to the degeneration of the red blood corpuscles. Fat globules may appear along the lines of the vessels and nerves, and the walls of the former and the

sheaths of the latter may degenerate. The whole structure may break down into a greasy mass containing fatty acid crystals.

Structure.—As the dentine papilla it consisted of roundish cells with the so-called odontoblasts, soon making their appearance upon the surface. In young pulps the deeper cells are large angular, rounded, or spindle-shaped. In adult pulps they are chiefly stellate or angular.

The Odontoblasts.—A single layer of large elongated granular cells, each having a large neucleus at the end furthest from the dentine. They have probably no limiting membrane. According to Hopewell Smith they are not closely packed together, but separated. When treated with hardening re-agents such as alcohol, or with water or chromic acid, they shrink and show up well defined contours which are not seen in the fresh state. They vary in shape according to age When young they are pyriform, when active, squarish, aud when old, ovoid and shrunken. They have

Dentinal processes,—which enter the dentinal

tubes. There may be more than one to an odontoblast.

Pulp processes, — which communicate with the deep cells of the pulp, and according to some authorities.

Lateral processes,—which communicate with lateral processes of other odontoblasts. These if they do exist are exceedingly difficult to spot.

The cells of the pulp are arranged, as seen in transverse section, in a direction radiating outwards from the centre. The deeper ones grow out into processes which remain very fine, and the fibrous tissue present cannot be demonstrated unless the pulp has degenerated. This connective tissue imbeds the cells and slings the pulp up in its cavity.

The matrix of the pulp is of a mucoid protoplasmic character.

Vessels of the pulp.—Three or more branches from the superior and inferior dental and infra-orbital divisions of the Int. maxillary artery enter at the apical foramen, break into branches which are at first parallel with the long axis of the pulp, and finally form a plexus beneath the membrana eboris (odontoblasts).

The arteries are accompanied by veins and capillaries.

Nerves of the pulp.—

One large and three or four small trunks enter by the apical foramen, pursue a parallel course, and give off branches. They terminate very obscurely. They may form a rich plexus beneath the odontoblasts, they may end in the odontoblasts, they may pass between them to the under surface of the dentine, or they may penetrate the dentinal tubes.

Lymphatics. None are existent in the pulp.

The basal layer of Weil.

This occurs between the inner end of the odontoblasts and the outer surface of the pulp, and is comparatively pale and translucent. According to Weil, it consists of fine connective tissue which communicates with the processes of the odontoblasts. Mummery asserts that it is absent in the growing base of young teeth, and it is in the crown that it is most pronounced. Von Ebner doubts its existence, and attributes the appearance to the shrinkage of the pulp, the odontoblasts being held up to the dentine by means of their dentinal processes.

ALVEOLAR DENTAL PERIOSTEUM.

This is a connective tissue and has no elastic tissue. It contains two sets of fibres, the more important Sharpey's fibres and bundles of less conspicuous fibrous tissue. The general direction of the fibres is transverse. Near the bone they are in conspicuous bundles, whilst towards the cementum they form a fine network of interlacing bands and pierce that tissue. The actual attachment, however, is by white connective tissue fibres known as Sharpey's fibres. These are directed obliquely transverse, they pass through all the lamellæ of the cementum, where they are not fully calcified. The alveolar dental membrane is a single membrane, since vessels, nerves and fibres, can be traced throughout its whole thickness without any alteration in their course.

It contains the following cells.

Fibroblasts—which may be flattened or lamellar. They are supplied with neuclei and are joined together by processes.

Cemento or osteoblasts. Found on the sur-

faces next to bone and cementum, and produce either cement or bone,

Osteo clasts, or giant cells are seen where absorption is proceeding.

Epithelial cellular bodies or rests—are sometimes seen near to the cementum, and may originate from remains of the epithelial sheath of Hertwig, (This sheath is produced by prolongations of the internal enamel epithelium at the base of the dentine papilla,) or from remains of the Zahnleiste or tooth band. (Hopewell Smith.)

Gingival gland.—This so-called gland is a mass of cells at the gingival margin near to the attachment of the gum to the tooth. Black asserts that it has no glandular function. It encircles only a portion of the neck of the tooth and is sometimes absent.

Blood supply,- This is from the pulp, gums, and vessels of bone.

Nerve supply.—From nerves in bony canals and dental nerves.

Origin.—From the external layer of the tooth follicle.

Function.—Nutrition, and to sling up the tooth in its socket.

GUM. This is continuous with the mucous membrane of the mouth but is denser. At the neck of a tooth the gum is continuous with the periosteum on the inner side of the alveoli, and there is no distinct line of demarcation between them. Its deneness is due to its

(1) dense tendinous fasciculi which are fan-shaped.

(2) its being bound down to the bone by the blending of it fasciculi with those of the periosteum.

Single or compound broad based papillæ beset the gum. Its epithelium is stratified in character, flattened cells occupying the surface, cubical ones a little deeper, whilst deepest of all they are columnar, and form the *rete malpighii.*

The gum may be divided into *stratum corneum*, *stratum lucidum*, and *stratum granulosum.*

Fat lobules, mucous glands, and the Glands of Serres or pavement epithelium are also found in the sub-mucous tissue. The function of the latter is unknown The gum is rich in vascular elements but not in nervous.

Function. Nutrition and to act as padding for the bone.

CHAPTER IV.

NASMYTH'S MEMBRANE.

This is situated over enamel not covered by cementum. It was supposed to be cement. It may be removed by dilute acids. It is 1-20,000th of an inch in thickness, is indestructible, resisting the action of acids and alkalies is worn off speedily, and is not so hard as enamel. It consists of two layers, the outer having large hexagonal cells with nuclei, once thought to be impressions of the ends of the enamel prisms. They are, however, ten times larger than the latter, the inner marked by small hexagonal impressions, probably the impressions of the ends of the enamel prisms.

Origin.—It is derived from the epiblast, the external from the external enamel epithelium, and the internal according to Hopewell Smith from the spent cells of the internal enamel epithelium.

Function. To protect enamel.

DEVELOPMENT OF HUMAN TEETH

In dealing with development of the teeth, the notes will apply to the lower jaw for the sake of convenience. The process is similar in the upper.

Each tooth originally consists of an enamel organ and a dentine germ. These are universal. There is usually also a dentine follicle or sac. This, however, may not be present, e.g. (tooth germ of newt). Enamel is not always developed (see distribution of enamel).

The following changes take place before birth:—

40 to 45th day. An ingrowth of epithelium occurs around the future tooth-bearing portion of the jaw. The groove, thus formed, as seen in section, is filled in with cellular elements. The ingrowth of epithelium is known as the

primitive tooth band, and the heaping up of cellular elements as the Zahnwall.

7th week. The primitive tooth band splits up into two portions, the outer vertical portion being called the lippenfurche, or lip furrow, and the inner horizontal portion, the true tooth band, or Zahnleiste. Tomes mentions three theories concerning the development of the lip furrow and the Zahnleiste.

1. Röse. The Lippenfurche and the true tooth band originate from a common origin the primitive tooth band.

2. Baume. The true tooth band originates in the lippenfurche.

3. Leche. They have independent origins but arise simultaneously.

9th week. Near to the free end of the true tooth band, ten dippings in occur. These constitute the enamel organs of the ten temporary teeth.

Eight thickenings then occur in the mesoblastic tissue (the first eight dentine papillæ), whilst a little later two other dentine papillæ occur for the second temporary molars.

From prolongations backward of the true tooth band on either side, special dippings in

occur. These are the enamel organs of the six year-old molars. Their dentine germs arise almost stimultaneously at about seventeen weeks.

During development the true tooth band broadens backward, and from this broadened portion the enamel organs of the permanents develope, those of the incisors and canines at the twenty-fourth week, of the first premolars at the twenty-ninth week, and of the second premolars at the thirty-third week. (Röse, Hopewell Smith).

The enamel organs of the permanent second molars, and the wisdoms develope after birth similarly to those of the other permanents, those of the twelve years, three months, and those of the wisdoms three years after.

The dentine papillæ of the permanent teeth arise almost simultaneously with the development of their enamel organs.

Each dentine papilla rises up to meet its enamel organ which is being prolonged to meet the former. The enamel organ is at first club-shaped. Through pressure from the dentine papilla it becomes flattened and florence

flask shaped. Eventually the papilla pushes itself into the enamel organ which becomes bell-shaped investing the papilla like a cap. From the base of the dentine papilla, and according to some authorities, continuous with it, prolongations arise up and around the enamel organ. These constitute the dentine follicle or sac. Some authorities assert that this originates from the dentine papilla, others, that it occurs through a differentiation of cellular elements in close proximity to the enamel organ. The latter theory is probably correct.

Conclusion. In origin the enamel organ is ecderonic or epiblastic, the dentine papilla and the dentine follicle, enderonic or mesoblastic.

Structure of the Enamel Organ.

When the enamel organ is bud-shaped the peripheral cells are columnar, the central cells polygonal. Later the central cells become stellate in character. Between the stellate reticulum and the internal enamel epithelium occurs a narrow layer of cells, the stratum intermedium. When the papilla makes its appearance the peripheral enamel cells next to it become elongated and specialized, and form

the layer of enamel cells or ameloblasts. The other peripheral cells do not enlarge, and form the external enamel epithelium.

The enamel organ therefore consists of, from without inwards.—

The external enamel epithelium.
Stellate reticulum.
Stratum Intermedium.
Internal enamel epithelium.

External enamel epithelium :—This consists of cubical or rounded cells.

Function.—To form Nasmyth's membrane. (external layer).

Stellate Reticulum :—This is composed of stellate or star like cells from which spring long processes. The interspaces are filled with fluid portions rich in albumen, which are known as enamel pulps.

Function.--Although enamel may be developed without this layer, it probably keeps the space for, and determines the shape of the future tooth.

Stratum Intermedium : — The cells are intermediate in character between the cells of the stellate reticulum and the internal enamel

epithelium being small, polygonal and branched.

Function.—To nourish the enamel cells.

Internal Enamel Epithelium :—This consists of elongated columnar cells, hexagonal in shape. several times longer than they are broad, and having large oval nuclei at their ends furthest from the forming enamel. They are granular. Waldeyer states that they have no limiting membrane. They are called ameloblasts.

The function of the ameloblasts is to form enamel.

The Epithekal sheath of Hertwig,—is formed by the continuation downwards to the base of the dentine papilla of the internal enamel epithelium and may determine the shape of the future roots. (Hopewell Smith).

Hopewell Smith also mentions the *inner* and *outer ameloblastic membranes* of Leon Williams,—which are sometimes seen at either end of the ameloblasts, the inner, between the ameloblasts and the formed enamel, and the outer between the ameloblasts and the cells of

the stratum intermedium. The inner has been described as the *membrana performativa.*

Paul, Wedl, and Magitot say the enamel organ is unvascular, whilst Beale asserts that there is a vascular network in the stratum intermedium.

Structure of the Dentine Papilla.

This consists of myxomatous tissue and is very rich in cells and vessels. At first the cells are rounded, later, the deeper cells become branched, and those on the surface become differentiated into the odontoblasts or membrana eboris. (For a description of these see pulp.)

The layer of odontoblasts has been called the membrana eboris, or ivory membrane, because it is often pulled away from the pulp when the dentine is removed, on account of its being so closely adherent to the latter.

Structure of the Dentine Follicle or Sac.

In the first stage the follicle differs from the surrounding tissue in being denser and richer in cells and vessels. When fully developed the sac consists of two layers, an outer dense, which forms the alveolar dental membrane,

and an inner loose, which forms cementum, osteoblasts or cementoblasts being developed in its structure.

Where there is to be coronal cementum as in ruminants, it is probable that a special cement organ of a cartilagenous character is developed between the follicle wall and the enamel organ.

Gubernaculum. A bundle of fibrous tissue passing through the apex of each tooth crypt.

Function. It was once thought to be, to direct the passage of the tooth into its place.

CHAPTER V.

DEVELOPMENT OF TEETH IN VARIOUS CLASSES.

Fish. *Teleostei* (bony fish):—Here there is no Zahnleiste and each tooth germ arises independently.

Elasmobranchii (cartilagenous fish): Here there is an inflection of epithelium or Zahnleiste which is continually growing. It is situated down the side of the jaw and the enamel organs are developed in it. The dentine germs are developed from connective tissue beneath. There is no follicle. There is a continuous succession of teeth, and those not in use are covered and not fully calcified.

Amphibia. *Newt*:—A tooth band exists. The germs have no follicles.

Frog:—It is not known whether the enamel

organs are derived from a tooth band, or develop independently

REPTILIA. *Crocodilia.*:—Development like man with the exception that the succeeding teeth erupt into the same sockets as the preceeding ones.

Lizards:—The teeth germs are formed a long way beneath the surface, the enamel organ being greatly elongated to meet the dentine papilla, which is at first situated deeply. There is neither stellate reticulum nor stratmu intermedium in the enamel organ, according to Hopewell Smith and others.

Ophidia:—The enamel organs are derived from a tooth band. The germs are at first vertical but eventually when near to the surface they assume a horizontal position. The germs not in use are surrounded by a capsule, and this area is known as the "Area of tooth development."

CALCIFICATION OF HARD TISSUES.

Dentine is the tissue to form firstly, enamel next, and cementum lastly, the salts being derived from the blood.

Formation of Enamel.

The true manner of its calcification is not known. The following are the more important theories.

(1) Actual calcification and conversion of the ameloblasts. (John Tomes.)

(2) Excretion from the ameloblasts. (Charles Tomes, Leon Williams, etc.)

(3) The ameloblasts grow near to forming enamel, and this new growth becomes calcified into enamel. (Schwann).

The following are the conclusions of Charles Tomes:—

(1) The ameloblasts themselves do not calcify.

(2) Enamel is excreted from the ameloblasts, which during the process recede.

(3) Each ameloblast furnishes a fibrillar process, continuous with its own plasm, which serves for the entire length of one enamel prism.

(4) Each fibril undergoes calcification from without inwards, the process reaching the central axis except in tubular enamels.

The following may be said to be facts in

connection with the calcification of enamel.

1. Osteo-genetic fibres, calco-globulin and lime salts occur in the corners of the ameloblasts next to the forming enamel, toughening them.

2. These changes spread upwards and inwards.

3. The ameloblasts can be pulled away from the forming enamel, the hardened corners remaining behind. Each cell now presents a process (Tomes' process).

4. During calcification Tomes' processes become everted and have trumpet like mouths. The nuclei of the ameloblasts become large and oval and are sometimes squarish, sometimes angular, and sometimes crescent shaped. The ameloblasts contain granules of a highly refractive nature which stain black with osmic acid.

Formation of Dentines.

Dentine is formed from without inwards, so that there is no increase externally.

Theories of formation.

1. The odontoblasts become incorporated

in the dentine, the outer part of the cells becoming gelatinous, this being the seat of calcification. The intermediate part becomes partially formed (Neumann's sheaths), whilst the most central portion remains soft as the fibril. (Waldeyer, Boll and Beale).

2. Same as above, with the exception that the outer part of the cells becomes fibrillar gelatinous (Von Ebner).

3 Dentine is excreted from the odontoblasts (Carl Huber).

4. The odontoblasts recede during the formation of dentine, each leaving behind a fibril, which keeps open the dentinal tube. They do not excrete the dentine, the formation of which is due to a calcification in fibrous connective tissue found on the surface of the pulp through the medium of round osteoblastic like cells of the pulp. (Mummery, Hopewell Smith, etc.)

Actual calcification of Enamel and Dentine—

Minute concentrically laminated granules embedded in calco-globulin combine with the calcium salts of the latter to form calco-spherites. These conglomerate and calcify *en*

masse to form the hard calcified material.

Formation of Plici-dentine—

This is similar to that of hard unvascular dentine with the exception that the pattern of the tissue formed is more complex, due to the existence of a complex pulp.

Formation of vaso-dentine—

Similar to ordinary dentine, with the exception that the capillary plexus just behind the odontoblasts does not recede with them, but remains stationary, so that they become involved in the tissue formed, calcification going on around them.

Formation of Osteo-dentine—

With osteo-dentine there is usually a thin layer of hard tubed dentine. With the exception of this, the dentine is formed by an internal calcification. Soft trabeculæ shoot through the pulp. These become covered with osteoblasts, through the agency of which they become calcified, so that eventually the pulp cannot be pulled out.

Formation of Cementum—

Cementum may be formed in two ways:

1. In membrane (roots).

2. In cartilage (coronal).

1. When the crown of a tooth appears through the gum, the roots have not formed, but the position which they are to occupy is surrounded by the vascular follicle wall. On the inner side of this, large cells exist (osteoblasts of Gegenbaur) or cementoblasts. Between these and the membrane, white connective tissue fibres exist. On the one side, these become connected with the cementum, and on the other with the bone, and persist as Sharpey's fibres. The osteoblosts of Gegenbaur are the formative cells of cement formed in membrane.

2. Between the follicle wall and the enamel organ, at about the period of dentine formation, a greyish vascular area may be seen which is firmer than the enamel organ. It becomes fibro-cartilagenous containing chrondroblasts, after the completion of the enamel and dentine. It is from these chrondroblasts that coronal cement is formed.

DEVELOPMENT OF THE JAWS.

Upper Jaw. This appears at about the twentieth day as two buds growing inwards

towards the median line. These are the maxillary processes. They originate from the base of the first visceral arch. The relations of the primitive buccal cavity are:—

Above. The fronto-nasal process.

Below. Meckel's Cartilage.

Sides. Maxillary processes.

Whereas the two portions of Meckel's cartilage meet one another and coalesce the maxillary processes do not, and the space between them becomes occupied by a prolongation downwards of cartilage from the forehead (naso frontal process) This consists of three portions, a median, which forms the intermaxillary bone, the two lateral, which fuse together and form the upper lip. Their outer edges fuse with the maxillary processes. The intermaxillary suture closes early.

Lower Jaw. Inside the first visceral arch, a cartilage is developed running from the base of the cranium to meet its fellow of the opposite side They fuse together in the median line. This bar of cartilage is known as Meckel's cartilage. With the exception of a small portion of the symphysis the lower jaw is not developed in

this. The malleus and incus bones of the ear however, are. The cartilage forms a foundation around which the lower jaw is built up, in membrane. Calcification starts about the 40th day. There are six centres, dentary, splenial, coronoid, angle, mento-mechalian, and condyle.

Splenial. This is like a shelf on the inner side of the jaw, situated above Meckel's cartilage and the inferior dental nerve. The teeth germs are situated on it. As Meckel's disappears this splenial portion joins the dentary, and so cuts off the mylo-hyoid branch of the inferior dental nerve. The portion above the inferior dental canal is developed for the milk teeth. When these are lost it disappears and re-forms for the permanents. After the loss of the permanents it permanently disappears. The portion below develops late and never disappears.

Appearance of Jaws at different Ages.—

Before birth.—The teeth germs are contained in a continuous gutter of bone. The sides of this groove rise as high as the tops of the teeth germs, but do not overarch them.

At birth.—The ascending ramus is at a very obtuse angle with the horizontal. The two halves of the lower jaw are not osseously united, but are joined together by fibro-cartilage. What was a continuous groove before birth is now seen to be separated into a number of crypts or alveoli, through the agency of bony septa which are not fully formed at the back of the mouth. The crypts for the centrals are larger within than at their orifices, and there are depressions on the lingual walls for the germs of the permanents. The septa between the centrals and laterals pass backwards and inwards towards the median line, so that the crypts for the centrals are wider in front than behind. The lateral crypts are *vice versa*. The canine crypts are anterior to the lateral giving a flattened appearance anteriorly. The condyle is still on a very low level. The antrum of Highmore is a mere depression on the wall of the nasal cavity.

Six months after birth.—The symphysis is well marked. The mental foramen is noticeable. The crypts for the six-year-old molars appear, but they are incomplete. The cells

for the permanent centrals are well marked, whilst those for the laterals are depressions on the lingual walls of the crypts for the temporary laterals.

Eight months after birth.—Anchylosis of the lower jaw occurs. The symphysis and the mental foramen are pronounced. The antrum extends under two-thirds of the orbit. Eruption of the teeth has set in.

Seven years after birth.—The temporary dentition is complete and jaw much deeper.

Adult.—The alveolar portion is deeper still. The ascending ramus is more at right angles with the horizontal.

Aged.—The ascending ramus has almost the same relation to the horizontal as at birth, forming an obtuse angle with it. There is also a loss of teeth and absorption of the alveolus.

Changes preceding teething.—General increase in size, the crypts increase in depth, and the edges of the crypts bend inwards over the tooth sacs.

Calcification at birth.—Half the crowns of the centrals, a little less than half the crowns

of the laterals, the tips of the canines, the masticating surfaces of the first temporary molars, and the cusps of the second temporary molars irregularly united by dentine.

Fixed points for measurement.—

1. Genial tubercles.
2. Inferior dental canal and orifice.
3. Mental foramen.

There is a slight addition to the mental foramen since the periosteum adds tissue to the surface and this lengthens the canal, directing it outwards and upwards. This happens soon after birth. In the temporary dentition it is situated beneath the centre of the first temporary molar, whilst in the permanent dentition its situation is between the first and second pre-molars.

Genial tubercles.—In the fœtus these are situated just below the central incisor crypts. Their relation to the permanents is the same, and therefore they are truly fixed points.

Enlargement of the Lower Jaw.—This is principally backwards by an absorption at the

base of the coronoid process and a deposition at the angle.

The front twenty permanent teeth succeed vertically the temporaries into the same positions.

CHAPTER VI.

Eruption of the Teeth.

Theories for cause—

1. Blood pressure (Constant).

2. Rotary movement of mucous membrane carrying teeth with it.

3. Pressure from elongation of the root.

4. Pressure from deposition of bone in the crypt.

With respect to 3 and 4, as the crown of a tooth often travels a further distance than would have been effected by either of these causes, they are probably incorrect. Again, teeth with stunted roots often erupt and fully formed teeth sometimes never erupt.

The theory of blood pressure is more plausible. During eruption there exists an exces-

sive quantity of blood in the part, and pressure from this probably forces the tooth in the direction of least resistance.

Process.

The alveoli of the temporary incisors are absorbed. This goes on chiefly over the anterior wall, which is removed, the bone behind remaining to help in the formation of the crypts for the permanent teeth. When the crown of the tooth appears through the gum, a deposition of tissue commences and this embraces the neck. The roots and jaw deepen, firstly in the incisor region. Eruption is not continuous, and the periods of rest which occur, allow of recuperation. The eruption of the first dentition is complete at the end of the second year. When the permanents are about due (sixth year), spacing of the temporary teeth occurs, and they lie more anterior.

General Relation of permanents (unerupted) with erupted deciduous teeth.

The canine is far above and out of the arch.

There is slight overlapping of the laterals and centrals.

The premolars are beneath the roots of the temporary molars.

The permanents erupt in a similar manner to the temporaries after absorption of the alveolus.

The permanents stand obliquely when erupted, the temporaries vertically.

The agents determining articulation—

1. Tongue.
2. Lips.
3. Opposition, upon upper and lower teeth meeting.

Absorption.

Some assert tbat the absorption of the temporary teeth is due to pressure from the permanents, others that absorption is due to pressure from an absorbent organ, acting in either of three ways.

1. Acid secretion.
2. Phagasitosis.
3. Amæbiform process.

Absorption, however, is probably not dependent upon pressure.

Process. Upon any part of the roots of the temporary teeth cup-shaped depressions may exist. These coalesce, enlarge, and destroy the tissue. The cementum is attacked firstly, and then dentine, except a very resistant portion in lose proximity to the pulp. Near to the teeth undergoing the process there exists a soft vascular tissue upon the surface of which are giant cells, osteoclasts, or absorption cells, which are contained in the cup-shaped depressions (Howship's lacunæ). The absorption of the temporaries is physiological whilst of the permanents it is pathological, the process, however, being similar.

Attachment of teeth—

1. Gomphosis.
2. Fibrous.
3. Anchylosis.
4. Hinged.

1. Gomphosis. This occurs in man, mammals, some reptiles, and the pristis or saw fish. A membrane (alveolar dental membrane) exists between the tooth and the socket of bone, in

which the former is situated. Removal by decease of this membrane would cut off nourishment from the tooth. In some reptiles socketed teeth occur, but differ from those of man etc , in that the succeeding rows of teeth come into the same sockets as were occupied by the preceding ones. In the pristis the gomphosed teeth grow from persistent pulps.

2. Fibrous. This attachment occurs in connection with the teeth of sharks. The teeth are attached to the membrane of the jaws by means of slips of the membrane passing up to attach themselves to the teeth. The rotation of the mucous membrane over the jaw brings the successional rows of teeth into place. In the Sargus or sheep's head fish each tooth is perched upon a pedestal of bone, and is connected with it by means of an annular ligament.

3. Anchylosis. Here the teeth and the bone are connected and there is no intervention of soft tissue. Sometimes they are so intimately connected with one another that it is difficult to tell where one one begins and the other ends.

Usually union of the tooth and bone takes place through the medium of osseous cylinders (*bone of attachment*), the pulp cavity of the tooth being continuous with the hollow of the cylinder. When the teeth are shed the hollow cylinder is absorbed to the level of the bone of the jaw, and another is formed for a succeeding tooth.

Examples—

Eel. The teeth are situated upon hollow cylinders of bone which differ in lamination from the bone of the jaw. The attachment is acrodont, that is, the whole of the base of the tooth rests upon the bony cylinder.

Haddock. As in the eel, except that the attachment is pleurodont, that is, a portion only of the base of the tooth, in this case the outer part, rests upon the bony cylinder, the inner portion passing within the hollow

Mackerel. The teeth are slung up between the plates of the bone of the jaw by means of osseous trabeculœ which pass between the inner side of the alveolus and the outer side of the teeth.

Development of osseous cylinders—

Soft trabeculæ spring between the bone of the jaw and the teeth. These become lined with osteoblasts through the agency of which they become calcified, and so produce the cylinders.

4. Hinged teeth. Occur in the Cod, Hake Angler, Pike, Odontostomus Hyalinus, and the Bathysaurus·ferox.

Angler. Here the hinged teeth are supplied posteriorly with fibrous elastic ligaments. On the teeth being bent inwards these become compressed, returning to their original positions upon force being removed.

Hake. The teeth have elastic hinges. The pulps are very vascular and the vessels pass through foramina in the hinges, which prevent their being injured. The free edge of the base of the tooth is thickened and rounded and adapted for resisting shock. This edge is on a higher level than the edge to which the hinge is attached, and fits upon a buttress of bone, therefore the tooth cannot be bent outwards without injury to the ligament. This

arrangement is for catching fish. The hake has other teeth which are anchylosed.

Pike. This fish has anchylosed and hinged teeth. In the hinged variety, rods shoot down through the pulp, but remain soft and elastic. They are attached to all parts of the tooth, but only to the hinged side of the bone of attachment. The hinge itself is not elastic and the elasticity of the arrangement is due to these soft trabeculæ. This adaptation is for swallowing.

Relation of the Teeth to other Dermal Appendages.

Teeth are called dermal appendages on account of the relationship of their development, with the development of hair, scales, etc. That the development is similar may be observed in the young dog fish, where the mucous membrane of the mouth is continuous with the external skin. There is no line of demarcation between the two, and the spines outside are continued into the mouth. Later when the mucous membrane of the mouth

becomes marked off from the external skin, the internal spines become more fully developed and form the teeth. Teeth and scales of the shark are similar in structure. Teeth are therefore *homologous* to other dermal appendages. The following are several examples of the relation of growth of teeth with other dermal appendages and other organs.

Examples—

1. Where horns develop, canine teeth are absent, or vice versa, (deer, etc.)

2. Castration of pig stops growth of canines.

3. Skin of edentates and structure of teeth peculiar.

4. Inherited baldness usually associated with inherited deficiency of teeth.

5. Almost hairless dogs in Turkey have few teeth.

6. Abnormally hairy people usually have few teeth.

Definitions of Teeth.

Incisors. The upper are those situated in the inter-maxillary bone. The lowers are those teeth which oppose the uppers.

Canines. The upper is the first tooth past the inter-maxillary suture providing it is not too far behind. The lower is the tooth which bites in front of the upper.

Premolars. Those teeth in front of the molars; they are usually more simple, and have displaced deciduous teeth.

Molars- The teeth behind the premolars, having no predecessors.

Difficulties in connection with Definitions.

Ruminants have eight lower front teeth all similar, the last one being called a canine because it bites in front of the upper canine, because it is the last tooth to erupt, and because six is the typical number of incisors. Tomes points out that the first reason is weak, because in the Oreodon, Lemurs, and Insectivora, the caniniform tooth bites behind the upper canine but is called a premolar. The second reason is also weak, for although the fourth tooth is the last to erupt, the periods of rest between the eruption of the other teeth are about the same as the period of rest between the eruption of the third and the fourth. The last reason is

also weak. An examination of the Oreodon, which besides having eight lower incisors has canines, will prove this.

Forms of Human Teeth.

Incisors, Upper Centrals. Crown oblong, the median angle is lower than the distal and more acute, and the labial surface is convex. The lingual surface terminates towards the gum in the cingulum. The pulp cavity terminates towards the biting edge in two cornua.

Upper laterals. Smaller than centrals, labial surface convex lingual surface flatter than that of centrals, the distal angle is more rounded than is the case with the centrals, and the cingulum is pronounced. Cornua as above.

Lower centrals Narrower than upper, and the necks are more constricted, the roots are flattened from side to side and the cingulum is not well marked . Cornua as above.

Lower laterals. Larger than centrals and the distal angle is rounded. The roots are flattened from side to side. Cornua as above.

Canines, upper. The point in which the crown ends is in a line with the long axis of

the tooth From this point, on either side is a slope, the distal being the longer. The lingual surface is convex and presents a ridge rnnning from the point to the cingulum which is well marked.

Canines, lower. Not so marked, lingual surface concave. point blunt, and there is no perpendicular ridge on the labial aspect, although this is feebly marked in the upper.

Premolars, upper. On the crown are two cusps, the outer being the larger. There is no ridge towards the gum. There is a transverse depression between the cusps, and the root is single and flattened from side to side in the second and often double in the first. The second differs also from the first in having a larger inner cusp. The pulp cavity ends in cornua.

Premolars, lower. Smaller, have two cusps, labial and lingual, which are joined by a ridge the outer cusp bends inwards and the inner is not well developed. The root is rounded. The second differs from the first in that the inner cusp is much more pronounced and the whole tooth is larger. Cornua as above.

Molars, upper. They have square crowns

with four cusps of which the antero internal is the largest. By means of an oblique ridge it is connected with the postero external. The cusps are separated by grooves which are continued on to the labial and lingual aspects of the teeth. There are three roots, one palatine and two buccal. The palatine is the largest. Sometimes the postero-internal cusp is suppressed. The upper wisdoms are often very small with the roots joined together. Pulp cavity ends in cornua.

Molars, lower. These have in 80 per cent of man five cusps on the first, four on the second, and five on the third. In the other 20 per cent they all have five cusps. One cusp is situated at each corner and one between and a little behind the postero-internal and the postero-externalcusps The roots are two in number flattened from before backwards and placed anteriorly and posteriorly.

Lower 3rd molar. Sometimes this tooth is large, the roots are often joined together and curved backwards.

CHAPTER VII.

MILK TEETH.

Homodonts are usually monophyodonts.

Heterdonts are usually diphyodonts.

Sometimes the milk teeth are lost very early (Mole, Bear &c.)

Sometimes lost in utero (seal).

In man they remain until about the seventh year.

In some mammals they remain until the adult stage.

Where only one set of teeth exists, it is nearly always the milk set.

Some assert that having no predecessors and arising directly from the tooth band, the permanent molars are milk teeth, others that they belong to a permanent dentition, others that they represent both series through a fusion of

the germs of both, others that each tooth is the last member of a separate series.

In *Cetacea*, milk teeth persist, except in the Balaenoptera rostrata, where the deciduous germs partially calcified are lost before birth.

In *Rodents*, poorly marked milk dentition except in hares and rabbits, which have three over three incisors, and six over four molars the latter beiug lost on the eighteenth day.

In *Carnivora*, well marked milk dentition except in aquatics.

In *Insectivora*, well marked milk dentition often remaining late, so that the permanent and milk dentitions are mixed.

In *Chiroptera*, Ill-developed milk teeth,

In *Primates*, well marked milk dentition.

In *Ungulates*, milk teeth well marked and remain late.

In *Edentates*, no milk dentition except in nine banded armadillo ond aardvark.

In *Marspuials*, Leche and others assert that the functional teeth are milk teeth and that the tooth which displaces other teeth is a pre-milk tooth. Others assert that the functional teeth

are permanents and that the tooth which displaces others is a milk tooth.

Sirenia. There is a fairly well marked milk dentition in the manatee, but only two incisors in the dugong.

COMPARATIVE DENTAL ANATOMY.

Introduction.

The present numerous forms of teeth have been derived from several simpler forms by slight modifications of those forms and their transmission through inheritance.

Nature's agents influencing form—

1. Adaptive modification or Natural selection.
2. Co-relation of growth or Concomitant variation.
3. Sexual selection.

Adaptive modification.—The suppression of things not needed and the increased development of things most used.

Examples of increased development—

1. Left tusk in male Narwhal.

2. Poison fang in snakes, (the more poisonous the snake, the more specialized is the fang).
3. Hinged teeth of fish (derived from former fixed teeth,, by certain modifications).
4. Sexual canines of wild boar and other animals.
5. Balaen plates of the Rorqual.
6. Incisors of rodents, wombat, aye aye, etc., etc.

Examples of Suppression—

1. Milk teeth of Rorqual.
2. Incisors in female narwhal.
3. Incisors of manatee.
4. Lower incisors of dugong.
5. Maxillary teeth of poisonous snakes. (The more poisonous the snake the fewer the maxillary teeth).
6. Upper incisors of female dugong, etc.

The foregoing examples of suppression prove that although natural selection affects the teeth, inheritance preserves to some extent organs which are of little or no use.

More animals are born into the world than

the world is capable of holding, so that a goodly number die off, namely those which are placed at a disadvantage (survival of the fittest), or sexual selection.

Sexual Selection.

Animals having certain characteristics giving them an advantage over others, are more certain to propagate their kind, e.g., sexual canines of primates, wild boar, sus babirusa, deer, etc., incisors of Narwhal, dugong and Ziphoid cetacean, horns of deer, feathers, and singing powers of birds, prolongation of cartilage from lower jaw of male salmon in breeding season.

Correlation of growth or Concomitant variation. (See page 57).

Theories for existence of multi Cuspid Teeth.

1. Due to coalescence of several simple cones (Rose, Kukenthal).

2 *Tritubercular theory.* In arriving at multi cuspid teeth there have been certain stages.

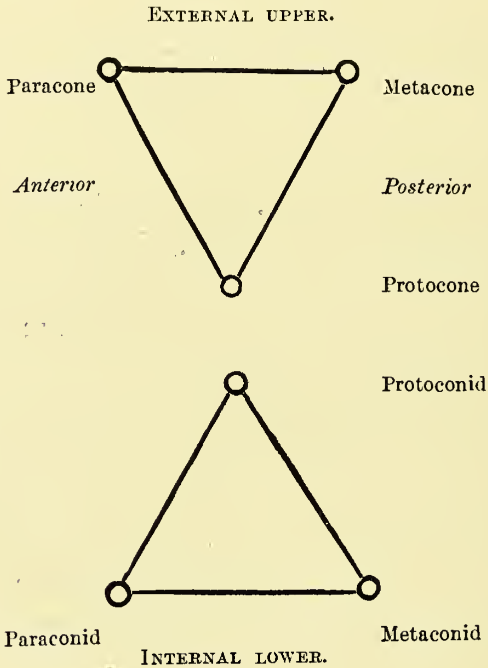
(a) Haplodont. A simple conical tooth.

(b) Protodont. Addition of accessory cuspules.

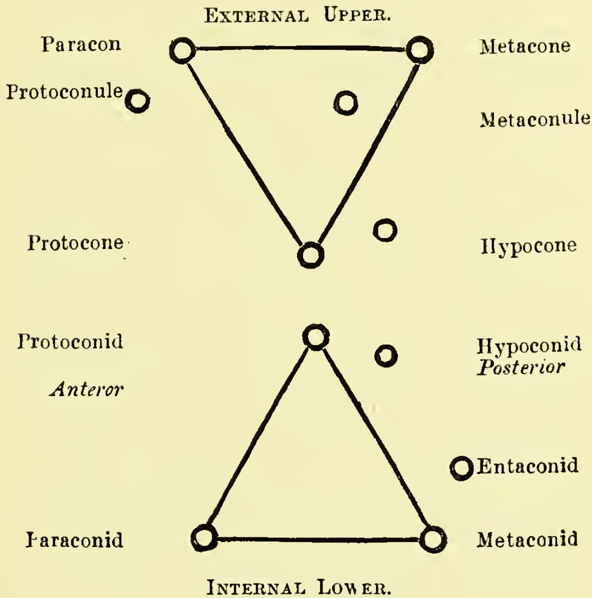
(c) Triconodont. One main cusp with two lateral accessory cusps in a straight line thusly :—$_\circ$ o $_\circ$.

(d) Tritubercular. The three cusps are arranged in a triangle. The original cusp or protocone is internal in an upper tooth and external in a lower.

The following diagrams show an upper and a lower tooth of the same side. The upper should therefore lie above the lower, but for purposes of description they have been drawn side by side.



This primitive triangle forms the foundation for the building up of multi-cuspid teeth by the suppression of one or more cusps and the addition of others. Cusps may be added thusly:—



3. Additional cusps formed by *elevations of cingulum.*

On the cingulum of a human tooth accessory cusps are sometimes present. In insectivora the well-marked cingulum is probably raised into accessory cusps.

EXAMPLES :—*Mastodon* and *Elephant.* (Ungulata).

Urotrichus an insectivora, has the cingulum

raised into three cusps on the outer and one on the inner aspect.

Mole, an insectivora, has three cusps on the outer cingulum.

In the *pig* the cingulum on the molars increases in size from I to 3, the third having it divided into a number of accessory tubercles.

In *tapir*, which is bilophodont the cingulum connects the outer ends of the two ridges. In the *rhinoceros* this becomes more fully developed, whilst when the tooth of the *horse* is reached, accessory pillars have come to be added.

Relation of Condyle to movement of Jaws.—

There is probably some relation between the condyle, the movements of the lower jaw and the forms of teeth.

Thus bunodonts have a cylindrical condyle.

Selenodonts have a condyle expanded and plain.

Lophodonts have a globular condyle.

Carnivora have a hinge joint.

Rodents have a condyle permitting only of an antero-posterio, or a posterio-anterior

movement except in leporidæ, where there exists a slight lateral movement also.

DEFINITIONS OF TERMS USED.

Homodont	=	All teeth alike.
Heterodont	=	Teeth differ in form.
Monophyodont	=	One set of teeth.
Diphyodont	=	Two sets of teeth.
Polyphyodont	=	Endless succession.
Acrodont	=	All on bone of attachment.
Pleurodont	=	Half on, half off.
Bunodont	=	Simple cones.
Selenodont	=	Bicrescentic, and elongated from before backwards.
Lophodont	=	Ridged.
Bi-Lophodont	=	Two ridges.
Brachyodont	=	Long roots, short crowns.
Hypsodont	=	Long crowns, short roots.
Haplodont	=	Simple conical.
Theocodont	=	Fangless teeth.

Gnathic Index.—Comparison of amount of brain with amount of mouth, and is obtained by multiplying the basi-alveolar length by 100, and dividing by the basi-o-nasal.

Orthognathous = below 98.
Mesognathous = between 98 and 103.
Prognathous = above 103

The basi-alveolar line is taken from the alveolar border between the two centrals of

the upper jaw to the anterior border of the foramen magnum.

The basi-o-nasal line is taken from the root of the nose to the same place. An older method of comparison was Camper's, viz.:

Facial Angle. = A line is drawn along the floor of the nose from the middle of auditory meatus to the tips of central incisors, and another from between the supra orbital eminences to the same place. These produce the angle, and the smaller the angle the smaller the amount of brain in comparison to size of mouth.

Objections to Camper's Method:—

(1) Undue inclination of teeth.
(2) Undue development of supra-orbital ridges.

Dental Index. = Comparison of size of teeth with amount of brain, and is got by taking the length of the cranio facial axis (obtained by taking a line from the front edge of the occi-

pital foramen to the naso frontal suture), and the length from front of first premolar to back of third molar, then

$$\frac{\text{Length of teeth} \times 100}{\text{Cranio-facial axis}} = \text{Dental index.}$$

Microdont = 42

Mesodont = 43

Megadont = 44 and upwards.

FISH.

General Notes.

(1) *Teeth* are usually numerous. The pipe and hippocampus are edentulous.

(2) *Use.* Usually prehension, crushing in cestracion philippi, rays, skates, and myliobates, and warfare in pristis.

(3) *Attachment.* Usually anchylosis, fibrous in sharks, gomphosis in pristis, Baracuda pike, Lepidosteus, and gill fish, hinged in cod, hake, angler, pike, &c.

(4) *Growth.* From non-persistent pulps. Persistent pulps occur in the rostral teeth of the pristis.

(5) *Succession.* Continuous. Usually from the sides of preceding teeth. From behind in sharks. Vertical in gymnodonts.

(6) *Form* May be rod shaped, conical, triangular, wedge shaped, or lamelliform.

(7) *Sexual differences.* Slight. In the breeding season the male salmon has a cartilagenous hook proceeding from lower jaw, and is then known as a kelt.

(8) *Structure.* May be cornified as in lamprey. May be calcified consisting of any of he dental tissues. Cementum is rare, and enamel usually a varnish.

CLASSIFICATION.

i. *Leptocardii,* fish having no heart, no jaws, no teeth. *e.g.*, Amphioxus.

ii *Cyclostomata* or *Leptocardii.* These are parasitic, have round mouths supplied with conical teeth, which are calcified in the myxine and bdellastoma and cornified in the lamprey.

iii. *Elasmobranchii* (cartilagenous).

iv. *Teleostei* (bony).

v. *Dipnoi* (mud fish).

vi. *Ganoideii* (sturgeon).

III.—ELASMOBRANCHII (sharks).

The jaws are not bony but consist of cartilage. They are supplied with concentric rows of teeth, fibrous attachment, triangular in shape, endless in succession, the teeth of the succeeding rows coming into the interspaces between the teeth of the preceding ones when the latter have been shed. The row in use is vertical, the others are procumbent and covered by mucous membrane. The usual structure is a varnish of enamel, hard tubed dentine and osteo dentine. The scales on the backs of sharks (shagreen) are similar in structure to the teeth.

Lamna. A shark, in which the several rows of teeth are in different degrees of recumbency, and the succeeding rows come into the positions of the preceding ones.

Carcharias. A shark, in which the teeth have convex posterior surfaces and serrated edges

Selache maxima. This shark has teeth upon the branchial arches.

Cestracion philippi. In this shark the teeth differ from those of typical sharks in being lamelliform. In the front of the mouth they are small, whilst further behind they are larger. They are blunt, but when first coming into use they are supplied with small points which become worn off. They have tubular enamel. The food consists of shell fish.

Rays and Skates. The teeth are something similar to those of the cestracion philippi, being blunter than those of ordinary sharks. In the *myliobates* the jaw is straight from side to side, and rounded antero-posteriorly. The teeth are arranged like a mosaic pavement, and as in rays and skates the structure is plici dentine. Live on shell fish.

Pristis (saw fish). The teeth in the mouth are like those of rays. There exists also a rostral snout supplied with teeth which are gomphosed, have plici dentine, and grow from persistent pulps.

IV.—TELEOSTEI.

Chaetodonts have fine teeth supplied with vaso dentine and hooks of enamel.

Pike has numerous teeth, anchylosed on the margins of the jaw, the lingual bone, the three median bones and the intermaxillary bone. Hinged on the vomer and the palate bones. On the vomer they are directed backwards and outwards, and on the palate bones backwards and inwards. The structure is chiefly osteo-dentine.

Sword fish has a long protruding snout on the under surface of which are rudimentary teeth.

Wolf fish (*Anarrhihas lupus*) has blunt conical teeth on the intermaxillary bone opposed by similar ones in the lower. Similar teeth also exist on the vomer and the two palate bones. They are anchylosed.

Hake and *Angler*. Have two rows of teeth, the outer anchylosed and the inner hinged.

Gymnodonts, including diodon, tetrodon, scarus and pseudo scarus.

Diodon. The teeth in the front of the mouth are fused to the bone, form a beak, and are not covered by the lips. In the mouth behind the front teeth are a number of teeth fused together which help in treatment of food. The beaks have a vertical succession.

Tetrodon. The beaks are similar to those of the diodon, but the upper and lower plates are divided into two, hence the name. They have a vertical succession, and there are no discs inside the mouth.

Scarus (parrot fish). The beaks are divided more distinctly into several plates which have not become fused together. They have a vertical succession.

Pseudo scarus (false parrot fish). The beaks have a vertical succession, and the successional teeth are cemented together by cement or bone of attachment. The upper and lower pharyngeal bones are supplied with teeth like human incisors, the pulps of which are protected by secondary dentine upon the teeth wearing down.

Sargus has human-like incisors and tubular enamel, and the remains of vaso-dentine.

V.—DIPNOI.

Mud fish, lepidosiren, has four plates one on either side of each jaw anchylosed to the bone. Each plate has five deep notches. They consist of enamel and dentine. In the front of the upper jaw are two sharp conical teeth for prehension.

VI.—GANOIDEII.

Sturgeon. Edentulous except in larval state *Lepidosteus* has plici dentine.

CHAPTER VIII.

AMPHIBIA OR BATRACHIA.

(1) *Gymnophiona*, tailless, wormlike, subterranean.

(2) *Urodela* have persistent tails, small bifid enamel-tipped teeth. *Examples* newt, salamander.

(3) *Anura.* Tailless in adult life, born with gills, some persist, but they develop lungs. Heart has three chambers. No fins, but digits; Polyphyodont.

Examples: *Toad.* Edentulous.

Tadpole. Horny plates like turtles' bills.

Frog. Edentulous in lower jaw, small teeth in upper, anchylosed; vertical succession.

Structure. Hard dentine, varnish of enamel.

Extinct Labyrinthodon. Teeth in upper jaw; in the lower jaw was a double row; had palatine teeth. *Structure,* plici-dentine.

REPTILIA

They do not breathe by gills; and have a four-chambered heart. Most are carnivorous.

CLASSIFICATION :—

(1) *Chelonia,* tortoises, turtles.
(2) *Lacertilia* or *Saurians,* lizards.
(3) *Ophidia,* snakes.
(4) *Crocodilia,* crocodile, alligator and garial.

(1) CHELONIA

Edentulous; early tooth band; may be carnivorous or herbivorous, the margins of jaws being hard or soft.

(2) LACERTILIA.

Teeth are round cones or are pointed; may be serrated; anchylosed polyphyodont;

either acrodont or pleurodont; hard dentine with enamel cap.

EXAMPLES:—

Mexican lizard (*heloderma*). Teeth grooved back and front. Poisonous.

Rhynco cephalian or hatteria (*sphenodon*), has two rodent like incisors on inter-maxillary bone; other teeth small; teeth anchylosed and acrodont; tubular enamel.

Varanus or *Monitor lizard* has plici-dentine.

(3) OPHIDIA (snakes).

CLASSIFICATION BY POISONOUS QUALITIES.

(*a*) *Typhlophedal.* Small, subterranean, slightly distensible jaws; non-poisonous, *e g.*, Uropeltidæ, Typhlopidæ.

(*b*) *Colubrines.* Non-poisouous, kill by crushing, *e g*, python.

(*c*) *Colubrines venemosi.* Poisonous, *e.g.*, cobra, sea snake (hydrophis).

(*d*) *Viperines.* Most poisonous, *e.g.*, viper, puff adder, rattlesnake.

CLASSIFICATION BY FORMS OF TEETH. (Tomes and others.

(*a*) *Aglypha.* None of the maxillary teeth grooved or canaliculated, *e.g.*, python, &c.

(*b*) *Opisthoglypha.* One or more of the posterior maxillary teeth are grooved, *e.g.*, whip snake, &c.

(*c*) *Proteroglypha.* The front teeth on the maxilla are grooved or tubular, *e.g.*, hydrophis, viper, &c.

EXAMPLES :—

Python has one lower row of teeth and two in the upper jaw. In the upper the outer row is on the maxilla and the inner on the palatine and pterygoid bones. Teeth curved and anchylosed; lower jaw elastic at symphysis. The germs which replace others lie parallel to the surface wrapped around by a capsule; this is known as the *area of tooth development*; *structure*, hard dentine and enamel. Polyphyodont.

Dazypeltis or Rachiodon. Rudimentary teeth; lives on eggs; spines exist on the anterior surfaces of vertebrae for breaking egg shells.

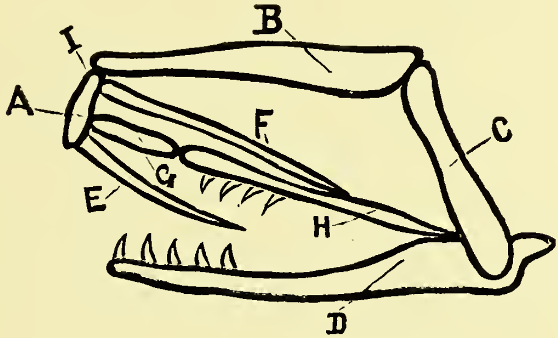
Hydrophis (*sea snake*) has five teeth on the

maxilla, the first of which is specialised and grooved anteriorly for poison.

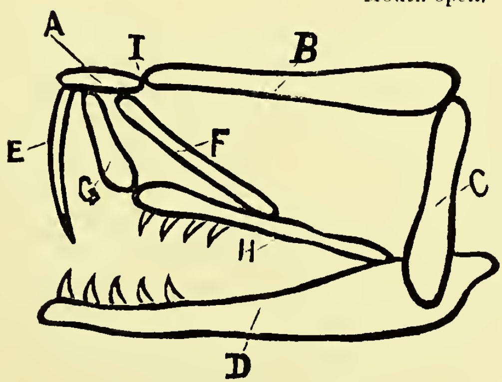
Australian death adder and cobra. The maxilla is shorter in comparison with less poisonous snakes. The poison fang is specially developed with only one small tooth behind it. The groove on the front of the fang is closed by a meeting of the edges which are round; maxilla is slightly mobile. In cobra and very poisonous snakes the poison is derived from the parotid gland. The duct does not reach fang, but is connected with it by a flap of mucous membrane, which prevents escape of poison. The cobra bites like a dog.

Vipers, Puff Adder, Rattlesnake. Very short maxilla; fang only tooth on maxilla, and is only erect when in use; it is canaliculated, and canal ends just above point suggesting hypodermic needle. Duct of gland does not enter fang, but is joined with it as in cobra by a flap of mucous membrane. The fang is erected by a rotation of the maxilla, *e.g.*,

Mouth closed.



Mouth open.



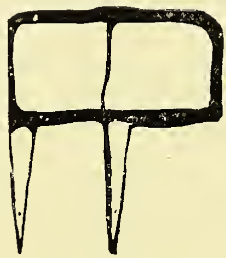
(*a*) Maxilla. (*e*) Fang.
(*b*) Skull. (*f*) Transverse bone.
(*c*) Quadrate bone. (*g*) Palate bone
(*d*) Lower jaw. (*h*) Pterygoid bone.
(*i*) Lachrymal hinge.

The actions of the external pterygoid and temporal muscles produce erection of the fang

and squeeze the poison out of the gland. In the viper the canal is closed by the meeting of the edges, which are flattened against one another. In the viper's fang there is no enamel in the canal, whilst there is in the cobra's.

Succession of fangs in viperine snakes.

Upon each half of the maxilla there is room for two fangs, but only one is in place at one time situated at either extreme, thusly :—



When the tooth in use falls out it is succeeded by another at the other extreme. The position of the two fangs is usually as seen in foregoing diagram. Sometimes they are symmetrical, but then one is usually loose. The succeeding fangs are arranged in pairs. They erupt vertically until they lie near the surface, when they become recumbent, suggesting rapid suc-

cession. When one fang is lost its bone of attachment is absorbed and a new bone of attachment forms for new fang.

(4) CROCODILIA.

Polyphyodont; vertical succession; gomphosis; teeth various sizes; sharp and conical.

Crocodile Specialised large lower teeth bite outside uppers. The dentine shows well marked interglobular spaces, whilst in the enamel the brown striæ of Retzius show up well. Cement occurs on the roots.

Alligator. The specialised large lower teeth bite into pits in the upper jaw. In both alligator and crocodile the attachment is gomphosis, and the succeeding teeth erupt into the same sockets as the preceding ones occupied.

BIRDS.

At the present time no birds have teeth. Fossils prove that birds once possessed teeth.

Icthyornis had gomphosed teeth. Succession as in crocodile.

Archæopteryx possessed teeth.

Hesperornis had teeth situated in a continuous groove, reptilian in character.

The beaks of present-day birds are adapted to their forms of food. Those of insect eaters are long, pointed and slender. Those birds which separate food from sand, &c., such as geese and swans, have long flat beaks with sensitive edges, whilst hawks and vultures have beaks which are hooked, very sharp and strong for tearing flesh.

CHAPTER IX.

Mammalia may be divided up into:—

(1) *Prototheria* Low in mammalian class, *e.g*, Ornithorhynchus and Echidna.

(2) *Metatheria.* Low, but not so low as Prototheria in mammalian class, *e.g.*, Marsupials.

(3) *Eutheria.* Mammals which suckle their young.

(1) PROTOTHERIA.

Monotremes Monotremes include Ornithorhynchus, Echidna and Proechidna. The genital and urinary passage is one and the same.

Ornithorhynchus or Duck-billed platypus. The jaws are wide and flat and each possesses four plates. The anterior ones are long

and narrow and the posterior ones broad and marked by depressions and elevations. They consist of cornified epithelium and similar hardened portions occur upon the tongue. The young animal has twelve teeth three on each posterior plate resting above the plates. They have broad crowns, narrow necks and short roots, the roots piercing the plates. When the teeth are lost the holes through which the roots passed become filled in.

Structure of Teeth.

Surface	=	Varnish of enamel.
Principal Cusp	=	Vaso dentine.
Body of tooth	=	Hard tubular dentine.
Root	=	As the root is approached a large number of interglobular spaces occur and the root itself is of a very poor structure.

Echidna (Old World Ant Eater) is edentulous.

(ii.) METATHERIA, *e.g*, Marsupials.

Marsupials Implacental mammals; do not

suckle their young. The young are carried about and protected in external pouches which contain nipples. The angle of the lower jaw usually presents the well marked pterygoid fossa. The lower jaw is often moveable at the symphysis. The milk dentition is not well marked and according to some authorities it is $\frac{1}{1}$ molar, except in the wombat, which some assert has no teeth that displace others. In the animals having this milk molar such as the thylacine, the kangaroo and the hypsiprymnus, the tooth which displaces it is exceedingly large and displaces a functional tooth also. Have tabular enamel except wombat.

Dental formula for Marsupials is $\frac{3.1.3.4.}{3.1.3.4.}$

Division of Marsupials.

	Diprotodonts	Polyprotodonts
Incisors	Never more than $\frac{3}{3}$	Numerous
Canines	Ill marked occurring only in upper jaw, or absent	Well marked
Cheek Teeth	Bluntly crowned	Sharply and strongly crowned

DIPROTODONTS.

Wombat. Formula $\frac{1.0.1.4.}{1.0.1.4.}$, Rodent-like in type, enamel on the fronts only of the incisors which is non-tubular. This is covered by cementum. Premolars simple, molars double. All teeth grow from persistent pulps.

Kangaroo. Formula $\frac{3.0.1.4.}{1.0.1.4.}$, Upper incisors vertical; the lowers are procumbent and grow from persistent pulps. Canines are absent; the cheek teeth are herbivorvous in type and the symphysis is moveable.

Hypsiprymnus (Kangaroo rat).

Formula $\frac{3.1.1.4.}{1.0.1.4.}$. Of the upper incisors the first pair grows from persistent pulps, the others non-persistent. They are vertical. The lowers are procumbent and grow from persistent pulps. Upper canines are small; the molars are squarish and have four cusps.

POLYPRODONTS

Thylacine (dog-headed opossum).

Formula $\frac{4.1.3.4.}{3.1.3.4.}$. Carnivorous in type, the incisors are small; the third caniniform; the

canines are strong and large; the pre-molars sectorial in type, and the upper and lower molars like the upper and lower carnassial teeth of the carnivora.

Dasyurus ursinus. (Tasmanian devil). Like thylacine but not so sectorial.

Dasyurus viverrinus. Insectivorous like in type.

Myrmecobius. Insectivorous like.

Opossums. The small are insectivorous
The large live on small mammals birds, etc.

CHAPTER X.

(iii) EUTHERIA, including edentates, sirenia, cetacea, ungulates, rodentia, carnivora, insectivora, chiroptera, and primates.

EDENTATES. *General characteristics.*

Most edentates have teeth but probably no member has teeth on the inter-maxillary bone. Some assert that the Aardvark has rudimentary laterals. True edentates such as the great ant-eater are edentulous. The animals are monophyodont with the exception of the nine banded armadillo and the aardvark which are diphyodont; and homodont with the exception of the two toed sloth and the aardvark which are heterodont, the former because the anterior tooth is much larger than the others and the

latter because the last milk tooth differs from the other teeth in being molariform. The structure of the teeth is usually hard dentine and cement, no enamel. The two toed sloth has hard and vaso dentine and the aardvark plici-dentine. All the teeth grow from persistent pulps with the exception of the displaced milk teeth. The sloths live on a vegetable diet, and the armadillos and ant-eaters on insects chiefly, although some of the armadillos eat animal food and vegetables. Examples :—

Two toed sloth. Formula $\frac{5}{4}$
Heterodont
Vaso Dentine
Add general characteristics.

Nine banded Armadillo,
Apply general characteristics
diphyodont.

Priodon, one hundred teeth
Apply general characteristics

Manis. (Scaly ant-eater).
edentulous.

Aardvark, Orycteropus. (Cape Ant-eater).
Plici-dentine.
Rudimentary laterals ?

36 teeth not all in place together.
Heterodont.
Diphyodont.
General characteristics.

SIRENIA. *General Characteristics.* Live in shallow coast waters and the estuaries of rivers. Have a vegetable diet. Possess the power of sitting up in the water in a semi erect position and give birth to one young at a time The intermaxillary bone is at an angle with rest of jaw. Include the dugong and manatee. The Rhytina is extinct. It had no teeth but horny plates.

Halicore or Dugong. Intermaxillary bone is at an angle with rest of skull and carries two incisors. In the *male* these protrude slightly from the bone, have enamel on the fronts and sides and grow from persistent pulps In the *female* they are completely buried, have enamel on the tips and non-persistent pulps.

In the young are two deciduous incisors in front of permanents.

The symphysis of the lower jaw presents about eight depressions. These at one time

carried teeth which were covered by plates of horn.

Molars. $\frac{5}{5}$. These are gradually lost until $\frac{2}{2}$ remain. They have no enamel but consist of dentine and cement.

Manatee. Intermaxillary bone is at an angle as in dugong. Incisors are functionless and covered, as with lower incisors of dugong.

Molars are 44 in number but only six are present on either side of each jaw at one time. They are bilophodont.

Structure. Simplest form of enamel (straight prisms), and the remains of vascular canals in the dentine.

CETACEA.

General Characteristics. Aquatic mammals unfit for terrestrial life including the toothed and balaen whales.

Structure of teeth. The dentine presents a great number of interglobular spaces (cetacean dentine), and in the cementum are numerous lacunæ and well marked lamellæ. Cetacea may be divided up into (1) *Odontoceti* (toothed whales) which are mostly homodont and mono-

phyodont and (2) *Mystacoceti* (balaen whales) which are mostly homodont and monophyodont.

(i) ODONTOCETI.

Dolphin about 200 teeth.
gomphosed.
conical and sharply pointed.
Porpoise about 100 teeth.
gomphosed.
blunt and flattened tips.
Grampus about 50 large teeth.
gomphosed.
conical and sharply pointed.
Narwhal. Edentulous in lower jaw.
Two tusks (incisors) in upper.

In *female* both buried, about eight inches long with non-persistent pulps. In *male* right one buried; left one ten to twelve feet long extending from jaw, has no enamel, consists of dentine, grows from a persistent pulp and has a spiral which runs from right to left. Sometimes the male has two of these tusks and then the spiral runs from right to left in both. (Tomes.)

In *young* are two milk teeth behind permanents.

Ziphoid Cetacean. Edentulous in upper jaw. Two strap shaped incisors in lower. These pass up, cross one another, and each ends in a denticle consisting of enamel and dentine. They pass outside the jaw and the denticles have the same direction as the shafts. The pulps become filled in with secondary dentine.

Sperm whale. Many teeth in lower jaw with fibrous attachment. A few buried teeth in upper.

(ii) MYSTACOCETI.

Balaenoptera Rostrata or *Rorqual.* 41 teeth germs in lower jaw, partially calcified

Heterodont because germs differ. Germs are lost in utero. Balaen plates are then developed in upper (several hundred).

They are triangular in shape cross the roof of the mouth but not the median line, where there exist smaller plates. The outer ones are calcified and the inner cornified and they grow from persistent pulps. The edges of the plates

fray out, and when the mouth is shut there is a triangular space in the middle, the floor being formed by the tongue. Water is taken into the mouth and by means of the frayed edges is sifted. It is then forced out sideways between the plates and the tongue sweeps backwards all animalculæ which may have been caught in the fringes.

CHAPTER XI.

UNGULATES. (*Hoofed Mammals*).

These develop large nails or hoofs for protection in walking, not more than four fully developed toes exist on each foot. Ungulates are diphyodont and heterodont.

CLASSIFICATION—

UNGULATES VERA

- Perissodactyle (odd toed)
  - Horse
  - Tapir
  - Rhinoceros
- Artiodactyle (even toed)
  - (1.) Suina (pigs, &c.)
  - (2.) Tylopoda (camels, &c.)
  - (3.) Tragulidae (chevrotains.)
  - (4.) Pecora (sheep, deer, &c.)

SUB-UNGULATES

- Hyracoidea
- Proboscidea
- Extinct sub-orders

ARTIODACTYLES.

Suina including pig, hippopotamus, sus babirusa, and wart hog.

Pig and wild boar. $\frac{3.1.4.3.}{3.1.4.3.}$

Incisors.—

1st pair of uppers touch at biting edges but not at bases. 3rd pair small and separated from others. Lower incisors procumbent and ribbed on upper surface with enamel.

Diastema.—

In front of upper canines.

Canines.—

The uppers pass forward, outwards and upwards, ribbed with enamel on under surface and grow from persistent pulps. The lowers are slender and sharp and pass forwards, outwards, and upwards. Triangular in shape, enamel on the two anterior surfaces. Grow from persistent pulps. Castration stays growth of canines, which are sexual weapons.

Premolars —

The first is small with one cusp and two roots and may be a temporary tooth remaining late or a permanent tooth erupting early. Second and third pass gradually to shape and size of fourth which has two cusps and four roots.

Molars.—

Have four cusps and four roots. The cingulum at the back gradually increases in size until in the third molar it has become greatly enlarged and divided into accessory cusps.

Sus babirusa. The teeth are similar to those of the pig with the exception of the canines. In the upper jaw the canines pass upwards, pierce the upper lip, and then after passing a short distance pass backwards and downwards sometimes piercing the skull and killing the animal. The upper canines were once supposed to be, to protect the eyes of the animal in passing through the brushwood in which it lives, but seeing that the female has only small upper canines and that it also lives

in brushwood, they are probably not adapted for that purpose but are more probably sexual weapons. (Tomes). They have no enamel and grow from persistent pulps.

Wart Hog, (Phacochoerus) All the teeth become lost until only the canines and last molars remain. The canines are very large and the last molar is as large as all the other cheek teeth put together, consisting of denticles of dentine and enamel joined together by cement. (Tomes).

Hippopotamus. $\frac{2.1.4.3}{2.1.4.3}$

Incisors.—

In the upper jaw the onter pair is the longer. They are vertical, grow from persistent pulps and are ribbed with enamel. In the lower they are procumbent, grow from persistent pulps, have tips of enamel and the median pair is the longer.

Diastema.—

In front of upper canines.

Canines.—

Grow from persistent pulps, the lowers being the larger.

Premolars.—

Simple, the 1st may be described similarly to the pig's.

Molars —

Bunodont, consisting of four tri lobed cones separated on crown surface by a crucial depression, the transverse groove being the deeper At first when worn down the crown presents four three lobed figures. Then the longitudinal depression goes and two four lobed figures remain. Eventually the transverse groove passes away and dentine of a simple pattern surrounded by enamel results. (Tomes).

(ii) TYLOPODA including *camel & llama.*

Camel. $\frac{1.1.3.3.}{3.1.2.3.}$ The upper *incisor* remaining is the outermost.

Canines.—

Large in both sexes, non-persistent.

Premolars.—

Those usually remaining are the 1st and last, the others being lost. 1st is caniniform.

Molars.—

Selenodont, concavities directed outwards in upper, inwards in lower.

(iii) TRAGULIDÆ. Chevrotains. Small animals like deer The males have large canines growing from persistent pulps, the females small ones with non-persistent pulps.

(iv) PECORA. Sheep, oxen, deer, etc.

Incisors.—$\frac{0.0.3.3.}{3.1.3.3.}$

None in the upper jaw, the lowers biting against a pad of gum. Eight teeth in lower, all incisor like but the last is called a canine.

Canines.—

Usually absent in upper jaw. Exist in both jaws in both sexes in most Cervidæ.

Cheek teeth.—

Selenodont as in tylopoda.

General Note. Where horns are present upper canines are absent and *vice versa.* An exception to this rule is the Indian Muntjac deer which has horns and upper canines. The latter however do not grow from persistent pulps.

PERISSODACTYLES including tapir, rhinoceros and horse.

Tapir. $\frac{3.1.4.3.}{3.1.3.3.}$

Premolars and molars.—

Bilophodont, with very little outer wall. Remains of vascular canals in dentine.

Rhinoceros. Formula doubtful.

Cheek teeth —

Selenodont. Outer wall more marked than in tapir. Transverse laminæ directed obliquely backwards. Spaces called sinuses exist and these remain open and are not filled in with cement.

Horse $\frac{3\,1\,4.3.}{3.1.4.3.}$

Incisors.—

Edge to edge bite, extend in jaw as they become worn; non-persistent pulps. On the crown surface a dipping in of the tissues produces "the mark" by which the age of a horse may be told After tooth is worn some distance this passes away and another mark appears in front of it, which is the exposed pulp protected by a formation of secondary dentine.

Diastema —

In front of upper canine. Formerly the horse had no diastema.

Canines.—

Rudimentary in mares occurring only in lower jaw. Occur in both jaws in stallion. Castration has no effect upon their growth.

Cheek Teeth.—

Selenodont. They were formerly bunodont

Hypsodont. They were formerly brachyodont.

They have a complex enamel structure and accessory pillars.

According to Huxley the cheek teeth of the horse have been derived from those of the tapir through those of the rhinoceros, by means of a development of the outer wall, the movement to a more oblique backward direction of the transverse laminæ, the filling up of the sinuses with cement, and the addition of accessory pillars.

Ages of horse—

At birth	....	Two incisors in each jaw.
5 years	...	Full mouth of teeth.

6 years ...	"The mark" begins to disappear.
12 years ...	"The mark" gone, stain remains.
12-13 years ...	Pulp covered by secondary dentine appears in front of "the mark."

SUB-UNGULATES.

Hyracoidea. *Hyrax* (biblical coney), $\frac{2.0.4.3.}{2.0.4.3.}$

Incisors.—

1st. upper pair rodent like and grow from persistent pulps, laterals are soon lost. Lowers are procumbent.

Cheek Teeth—

Like those of rhinoceros.

Proboscidea. (Elephant). $\frac{1.0\ 0.6.}{0.0\ 0.6.}$ or $\frac{1.0.3.3.}{0.0.3.3.}$

Incisors.—

The permanents are preceded by deciduous ones which are lost about the second year. The permanents have tips of enamel, grow from persistent pulps, and are composed chiefly of dentine or ivory, which is very elastic, this elasticity being due to the large amount of

organic matter, the great number of secondary curvatures, and interglobular spaces, and the fineness of the tubes. (Tomes). The tusks of the African are larger than those of the Indian elephant.

Cheek Teeth.—

One, and a portion of one are in place at one time. They come into place in a half circle, and the front part of a tooth is often worn away before the back part has fully developed. This arrangement diminishes weight and space. The teeth consist of several plates joined together by cementum, and there is one pulp chamber for each tooth. The plates when worn are lozenge-shaped in the African and slot-shaped and crinkled in the Indian variety.

EXTINCT SUB-UNGULATES.

Mastodon had the formula $\frac{1.0.0.6.}{1.0.0.6.}$

Incisors.—

Occurred in both upper and lower jaws, the uppers sometimes reaching to the length of twenty feet.

Molars –

Differed from elephant's in having nipple-like processes and transverse ridges.

Dinotherium had lower but no upper tusks, was aquatic in habits, using tusks for rooting up aquatic plants. The dentine was of a very poor structure.

CHAPTER XII.

RODENTIA.

General Characteristics.

They have a poorly marked milk dentition, except hares and rabbits which have a formula $\frac{3.0.6.}{3.0.4.}$. All teeth grow from persistent pulps except molars of rats and mice, which are human-like. The condyles are directed antero-posteriorly and are adapted for the gnawing movements of the jaws. Some have pigmented enamel, as the beaver, and some have tubular enamel, as the jerboa. The formula varies. In the rat it is $\frac{1.0.0.3.}{1.0.0.3.}$. In the squirrels it is $\frac{1.0.1.3}{1.0.1.3}$.

Rodents are characterized by their long scalpriform incisor teeth which, if they were produced, would form circles, the uppers small,

and the lowers large ones. The lowers are implanted very deeply and pass beneath the last molar. The purpose of this modification is to diffuse pressure. They have enamel on the fronts and sides, hard dentine further behind, softer dentine still further behind, and cementum at the back. This disposition keeps the teeth sharp (Tomes). The Capybara which is the largest of the rodents, has the last molar consisting of twelve plates (elephantine like), each plate or denticle having a separate pulp chamber.

CARNIVORA.

General Characteristics—

All are not truly carnivorous, the dog is generalized in its diet and the bear is herbivorous. They have well-developed muscular processes, especially the zygomatic. The milk dentition is well marked being $\frac{3.1.3.}{3.1.3.}$ except in felidæ which have the formula $\frac{3.1.3.}{3.1.2.}$ The tempero-maxillary articulation is a hinge joint. Incisors.—

Six in either jaw straight across the mouth. In some species the lowers are trilobed. Third incisor is caniniform.

Diastema.—

In front of upper canine.

Canines.—

Strong, long, and sharp, flattened from side to side and separated from pre-molars.

Premolars.—

Sectorial in type, the last one in the upper jaw being the carnassial tooth and characterized by having an anterior internal basal cusp. Sometimes the premolars are reduced in number.

Molars.—

Sometimes reduced in number. The first in the lower jaw is the carnassial tooth, and is characterized by a posterior basal cusp. The last molar in the upper jaw is sometimes within the arch.

Classification— (Tomes).

(1) Fissipedia (terrestrials).

(2) Pinnipedia (aquatics).

Fissipedia may be divided up into

(a) Æluroidea (cats, civets, hyænas).

(b) Arctoidea (bears, weasels, racoons).

(c) Cynoidea (dogs, wolves, foxes).

Pinnipedia may be divided up into

(a) Otaridæ (eared seals.)

(b) Phocidæ (seals).

(c) Trichechidæ (walrus)

FISSIPEDIA—

Cat, Lion, Tiger. Formula $\frac{3.1.3.1.}{3.1.2.1.}$

Truly carnivorous. Posterior tubercle on lower carnassial tooth not present or poorly marked Upper molar inside arch. Apply general characteristics.

Civet Cat. Lower carnassial tooth pectinated and insectivorous in type. Apply general characteristics.

Hyaena Formula $\frac{3.1\ 4.1.}{3.1.4.1.}$

Upper molar within arch. Cingulum well developed on cheek teeth for protecting gum from pressure from bones upon which animal subsists. Apply general characteristics.

Dogs, Wolves, Foxes. Formula $\frac{3.1.4.2.}{3.1.4.3.}$

Not so sectorial as cats, &c. Apply general characteristics.

Aardwolf. Well marked canines. Cheek teeth stunted. Lives on soft food.

Weasels. Dentition approaching type of bear's.

Racoon. Dentition still more like bear's, the teeth becoming more broad topped. Omnivorous.

Bear. Non-sectorial in type, cheek teeth broad topped and somewhat human-like. Canines not so pronounced. Formula $\frac{3.1.4.2.}{3.1.4.3.}$

PINNIPEDIA—

Eared Seals (sea lions). Canines large, other teeth homodont, teeth tend to erosion. Poorly marked milk dentition. Formula $\frac{3.1.4.1.}{2.1.4.1.}$

Other Seals. Formula $\frac{3.1.4.1.}{3.1.4.1.}$ Well marked canines. Cheek teeth have three cusps (tricono-dont).

Walrus. Formula $\frac{1.1.3.0.}{0.1.3.0.}$ Large canines growing from persistent pulps, used for progression over ice, tearing up marine plants and fighting (Tomes).

INSECTIVORA.

(*Mole*, *Hedgehog*, *Galeopthicus*, *Shrew*, *etc.*), live on insects, crushing the chitinous covering with their peculiarly adapted teeth which have sharp points. The molars are of the V or W shaped pattern, and have numerous sharp cusps.

Heterodont.

Diphyodont, the milk and permanent dentitions occurring together in the mouth for some time so that it is difficult at times to determine the formula.

Lower incisors small and recumbent. Canines often two-rooted (hedgehog). Tubular enamel occurs in the (Soricidæ).

Some have comb-like lower incisors (Galeopthicus).

Some have pigmented enamel (shrews).

CHIROPTERA (*Bats*).

(i) Insectivorous.
(ii.) Frugivorous.

Insectivorous. Formula $\frac{2.1.3.3.}{3.1.3.3.}$

Incisors small.

Large canines.

Pectinated cheek teeth.

Frugivorous. Formula $\frac{2.1.2.3.}{..1.3.3.}$

Teeth non-insectivorous in type.

Incisors large.

Small canines

PRIMATES—

Classification—

(1) Lemuridæ.
(2) Simiadæ.
(3) Anthropoid apes.

(1) *Lemuridæ.* Formula $\frac{2.1.3.3.}{2.1.3.3}$

Upper incisors small and spaced.

Lower incisors procumbent.

Upper canines large.

Lower canine ranged with the incisors and similar in type.

The first pre-molar is caniniform.

The molars have several cusps.

Aye-Aye (*Chiromys*).

Rodent-like incisors with persistent pulps.
Absence of laterals and canines.
Well marked milk dentition.
Formula $\frac{1.0.1.3.}{1.0.0.3.}$

(2) *Simiadæ.*

(a) *New World Monkeys.*
(b) *Old World Monkeys.*

(a) *New World Monkeys.* Formula $\frac{2.1.3.3.}{2.1.3.3.}$

Platyrrhine (broad nosed).
Prehensile tails.
Absence of cheek pouches.
No callosities on seat.

(b) *Old World Monkeys.* Formula $\frac{2.1.2.3.}{2.1.2.3.}$

Catarrhine (narrow nosed).
Non-prehensile tails.
Presence of cheek pouches, in many specimens also of callosities on seat.

Macaque Monkey.

Incisors directed obliquely forwards.
Diastema in front of canines (upper).
Upper canine grooved anteriorly and ridged at the back.
First lower premolar has two roots, and one cusp placed over posterior root
Molars have four cusps.

(3) *Anthropoid Apes*, including Gibbon, Chimpanzee, Gorilla, and Orang utan.

General Characteristics—

In giving these it will be well to compare the dentitions of apes and man.

APES.	MAN.
Incisors like man's but larger.	
Diastema in front of upper canine.	No diastema.
Canines large and sexual, eruping late. In gorilla erupt after third molar.	Canines non-sexual and erupt much earlier.
Upper pre-molars have three, and the lower two roots.	All pre-molars have one root except the first upper which has two.

APES.	MAN.
Upper, molars, have four cusps and lowers five.	Upper molars have four cusps and the lowers five on the six year old, four on the twelve year old, and five on the wisdom in 80 per cent. of man, whilst in the remaining 20 per cent. all the lower molars have five cusps
Intermaxillary suture remains open. Megadont. Prognathous. Heterodont. Diphyodont.	Intermaxillary suture closes early. Microdont. Orthognathous. Heterodont Diphyodont.
Jaws square, lines of teeth parallel, or tend to diverge	Jaws horse-shoe shaped, lines of teeth converging.
Molars increase in size from before backwards.	Molars decrease in size from before backwards.
Oblique ridge on upper molars passing from postero-external to antero-internal cusp.	Similar oblique ridge present.

The chimpanzee is most like man, the canines being non-sexual and the intermaxillary suture closing early. Prehistoric races of mankind stood nearer to apes than modern races. They were, in comparison to modern races:—

More prognathous.

The arch was squarer.

Wisdoms neither stunted nor crowded.

The lower 12 year molar had five cusps
Jaws large and strong.
Large canines.
Signs of attrition at biting surface

Typical Mammalian Formula $\frac{3.1.4.3.}{3.1.4.3.}$

In man, apes, etc., this formula is deficient and it is probable that the third incisors, the first premolars and the last molars are lost firstly. Man is gradually losing the third molars and the laterals.